

## CHEMISTRY 20L-1 - Cumulative Exam #1 (Winter 2018)

FORM A

NAME\*:

(LAST NAME)

(FIRST NAME)

UCLA ID#:

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**DO NOT OPEN THE EXAM UNLESS YOU ARE INSTRUCTED TO DO SO.****Exam must be taken during the lecture section in which you are officially enrolled.****CIRCLE THE NAME OF YOUR TEACHING ASSOCIATE\***

Tian (R 11:00AM &amp; F 2:00PM)

Yao (W 2:00PM &amp; F 11:00AM)

Ben (T 11:00AM & T 2:00PM)

Rongli (W 11:00AM &amp; R 8:00AM)

Yutong (T 6:30PM &amp; R 6:30PM)

Kony (R 8:00AM &amp; R 2:00PM)

**INSTRUCTIONS (Please Read Carefully)**

1. This exam consists of 3 questions (7 pages TOTAL).
2. Use PEN (**BLACK OR BLUE ONLY**) to answer ALL questions.
3. Indicate answers, including units, and show your method of calculation or reasoning. Place a box or circle around your final answer.
4. You must show ALL work for FULL credit. Answers should have the *correct number of significant figures and units*.
5. No credit will be given for a numerical answer alone or for an illegible answer or illegible work.
- \*6. **TWO POINTS** will be deducted from your total score for not circling the name of your TA or circling the incorrect name of your TA.

| Question | Score | Points           |
|----------|-------|------------------|
| 1        | 20    | 20               |
| 2        | 18    | 18               |
| 3        | 9.5   | 12               |
| Total    | 47.5  | (Max. 50 Points) |



By checking this box, I certify that I am officially enrolled in **Lecture 1**, the Lecture in which this exam is conducted.

You may use an SAT approved calculator during the exam.

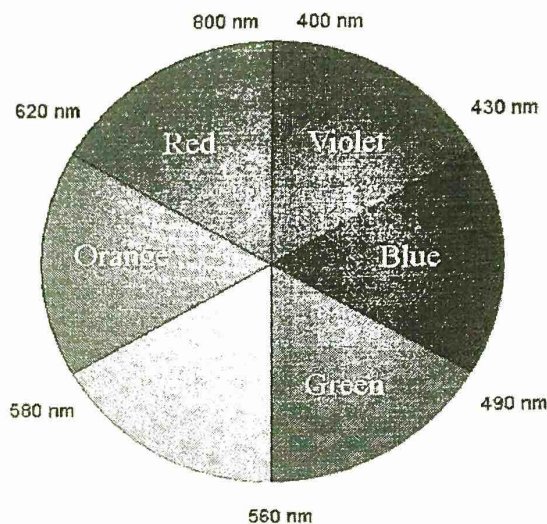
All other materials are **NOT** allowed during the exam.

Exam **MUST** be taken during the lecture in which you are officially enrolled on URSA.

## DO NOT DETACH THIS PAGE FROM EXAM

### Common Acid-Base Indicators

| Indicator         | Approximate pH Range for Color Change | Color Change      |
|-------------------|---------------------------------------|-------------------|
| Methyl Orange     | 3.2 - 4.4                             | Red to Yellow     |
| Bromothymol Blue  | 6.0 - 7.6                             | Yellow to Blue    |
| Phenolphthalein   | 8.2 - 10.0                            | Colorless to Pink |
| Litmus            | 5.5 - 8.2                             | Red to Blue       |
| Bromocresol Green | 3.8 - 5.4                             | Yellow to Blue    |
| Thymol Blue       | 8.0 - 9.6                             | Yellow to Blue    |
| Alizarin Yellow   | 11.0 - 12.0                           | Yellow to Violet  |



### Absolute Uncertainties for Various Volumetric Glassware and Equipment

5mL volumetric pipet:  $\pm 0.02$  mL

10mL volumetric pipet:  $\pm 0.04$  mL

50mL volumetric flask:  $\pm 0.04$  mL

100mL volumetric flask:  $\pm 0.08$  mL

25mL volumetric buret:  $\pm 0.03$  mL (for a pair of reading)

Digital Analytical Balance:  $\pm 0.2$  mg

Digital Spectrophotometer:  $\pm 1\%$  in %T

For very dilute aqueous solutions:

1 ppb = 1  $\mu\text{g/L}$

1 ppm = 1 mg/L

Useful Equations:

$$A = \epsilon LC$$

$$A = -\log T$$

$$P_A = P^\circ_A X_A$$

$$P_{\text{total}} = \sum_{i=1}^n P_i$$

$$\text{pX} = -\log X$$

$$\text{pH} = 14 - \text{pOH}$$

$$\text{pK}_a + \text{pK}_b = 14$$

$$K_a \times K_b = K_w = 1.00 \times 10^{-14}$$

$$\text{pH} = \text{pK}_a + \log \frac{[\text{conjugate base}]}{[\text{conjugate acid}]}$$

$$\text{Solution of quadratic equation for } ax^2 + bx + c \text{ is } x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$\text{Relative Average Deviation (RAD)} = \frac{\Delta \bar{x}}{\bar{x}}$$

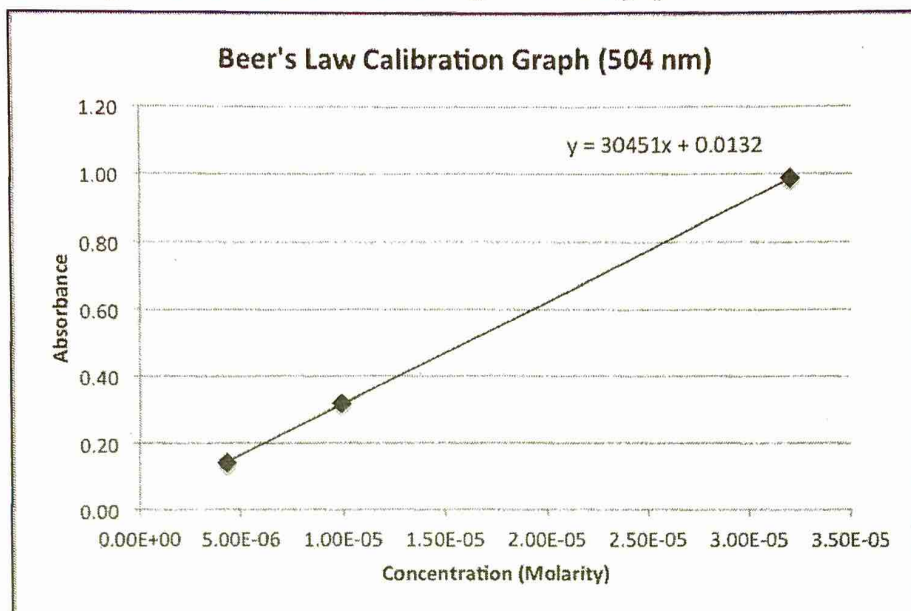
$\bar{x}$  = average value of the set of data or numbers

$$\Delta \bar{x} = \frac{\sum_{i=1}^n |x_i - \bar{x}|}{n}$$

where  $i$  is the counter (i.e. 1 ...  $n$ ) for the set of data or numbers

## DO NOT DETACH THIS PAGE FROM EXAM

Q1. Allura Red (FD&C Red 40, molar mass = 496.42 g/mol) is a common red dye that is used in cosmetics, medicine, and food in the United States. A student made three different solutions of Allura red dye and used them to construct a Beer's law calibration curve using the wavelength of 504 nm. The path length of the cuvette used was 1.20 cm. The equation for the line of best fit is given on the graph.



A student wanted to determine the concentration of Allura red dye in a 1.00 L bottle of red sports drink. The student used a 5-mL volumetric pipet to transfer 10 mL of the red sports drink to a 50-mL volumetric flask and then added distilled water to the mark on the flask. The absorbance of this diluted solution at 504 nm was 0.493.

- a. (5 points) Using the line of best fit given on the graph above, calculate the concentration (in Molarity) of Allura red dye in the diluted solution.

$$y = 30451x + 0.0132 \rightarrow y = A, \text{ELC} = 30451x$$

$$b.493 = 30451x + 0.0132$$

$$0.480 = 30451x$$

$$x = \boxed{1.58 \times 10^{-5} \text{ M}}$$

+5

- b. (5 points) Determine the concentration (in Molarity) of Allura red dye in the 1.00 L bottle of red sports drink.

$$(50.00 \text{ mL dilute})(1.58 \times 10^{-5} \text{ M dilute}) = (10.00 \text{ mL nondilute}) M_{\text{nondilute}}$$

$$M_{\text{nondilute}} = \boxed{7.90 \times 10^{-5} \text{ M}}$$

+5

$M_1 V_1 = M_2 V_2$



- c. (5 points) What is the concentration (in w/w%) of Allura red dye in the 1.00 L bottle of red sports drink? The density of the red sports drink is 1.03 g/mL.

$$\text{conc.} = 7.90 \times 10^{-5} \frac{\text{mol}}{\text{L solution}} \cdot \frac{496.42 \text{ g}}{\text{mol}} \cdot \frac{1 \text{ mL solution}}{1.03 \text{ g solution}} \cdot \frac{1 \text{ L solution}}{1000 \text{ mL solution}}$$

$$= 3.81 \times 10^{-5} \frac{\text{g solute}}{\text{g solution}}$$

$$\boxed{= \frac{3.81 \times 10^{-3} \text{ g solute}}{100 \text{ g solution}}}$$

+ 5

- d. (5 points) The Acceptable Daily Intake (ADI) of Allura red dye is 7.0 mg per kg of body mass. If a person weighing 150 pounds (68.0 kg) consumes 3.00 L of the red sports drink in a day, has he or she surpassed the recommended ADI for Allura red dye? Show work to support your answer.

Did the person surpass the recommended ADI (circle one)?

YES

NO

Show work below to support your answer:

~~68.0 kg~~ ~~7.0 mg~~

+ 5

~~$68.0 \text{ kg} \cdot 7.0 \frac{\text{mg}}{\text{kg}} \cdot 3.00 \text{ L solution} \cdot 1.03 \frac{\text{g solution}}{\text{mL solution}} \cdot \frac{1000 \text{ mL}}{1 \text{ L}}$~~

$$\frac{3.81 \times 10^{-3} \text{ g solute}}{100 \text{ g solution}} \cdot \frac{1.03 \text{ g solution}}{1 \text{ mL solution}} \cdot \frac{1000 \text{ mL}}{1 \text{ L}} \cdot \frac{3.00 \text{ L}}{1 \text{ day}} \cdot \frac{1000 \text{ mg}}{1 \text{ g}}$$

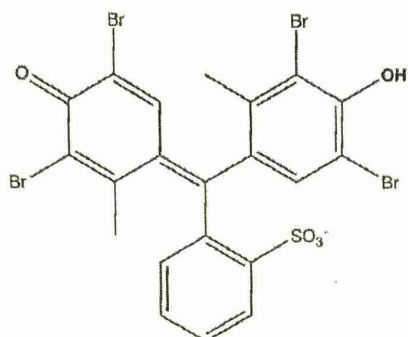
$$= 117.729 \frac{\text{mg}}{\text{day}} = 118 \text{ mg consumed in a day}$$

$$\frac{118 \text{ mg}}{\text{day}} \cdot \frac{1 \text{ day}}{68.0 \text{ kg}} = \frac{1.74 \text{ mg Allura}}{\text{kg body mass}} < \frac{7.0 \text{ mg Allura}}{\text{kg body mass}}$$

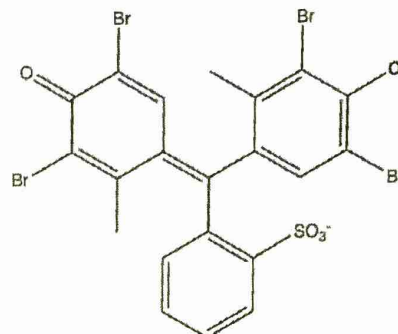
$$\boxed{1.74 \text{ mg/kg} < 7.0 \text{ mg/kg}}$$

$\therefore$  did not surpass ADI

Q2. Bromocresol green (BCG, molar mass = 698.01 g/mol) is a dye molecule that is often used as an indicator in titrations. The yellow form of the BCG molecule is the predominate form in solution when the pH is less than 3.8 while the blue form of the BCG molecule is the predominate form in solution when the pH is greater than 5.4. The structure of the acidic (yellow) and basic (blue) forms of the BCG molecule are given below.

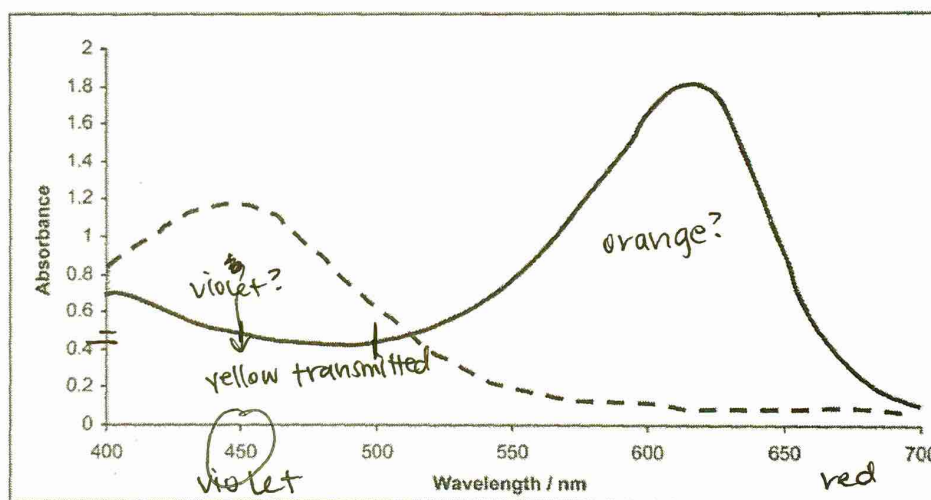


acidic  
Yellow 3-8



basic  
5.4 Blue

- a. (4 points) The absorption spectra of the yellow form and blue form of the BCG molecule are given below. Determine which spectrum (solid or dashed) belongs to the acidic (yellow) form of the BCG molecule. Provide a brief explanation to justify your answer.



color absorbed:

Spectrum belonging to acidic (yellow) form:

Solid Line

Dashed Line

#### Brief Explanation:

The color of the solution is the complementary color of the absorbed wavelength. If yellow appears, then purple is absorbed. Purple has short wavelengths of  $\sim 400$  nm. Purple absorbance is maximized in the dashed line spectrum. Thus, the dashed line corresponds to the absorbance spectrum of the yellow form of BCG-yellow.

- b. (4 points) Determine the molar absorptivity constant of the compound associated with the **solid line** at 450 nm. The solid line spectrum was obtained using a concentration of  $1.1 \times 10^{-4} \text{ M}$  for the compound and a path length of 1.00 cm.

Absorbance @ 450 nm  
looks to be ~~0.44~~  
~0.50

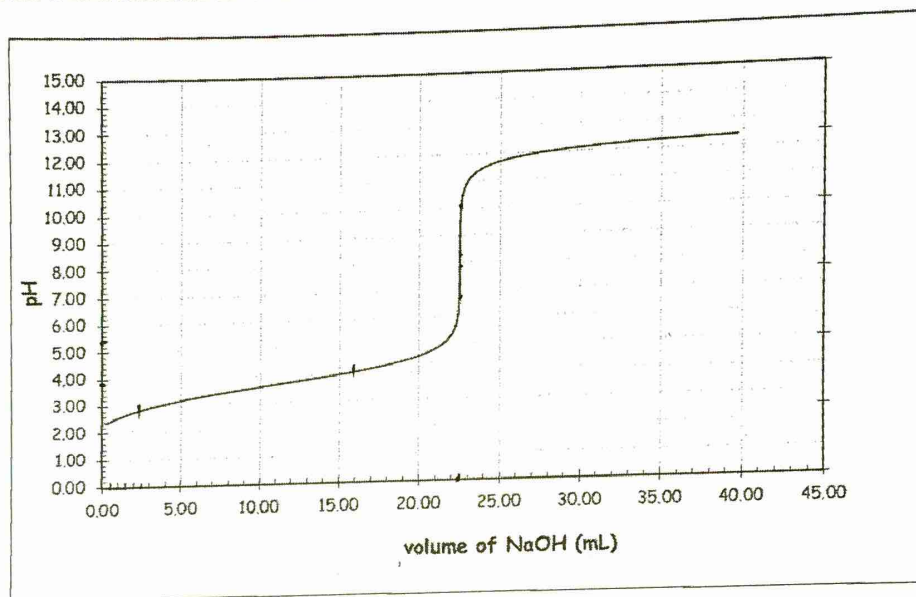
$$A = \epsilon L C$$

$$0.50 = \epsilon (1.00 \text{ cm}) (1.1 \times 10^{-4} \text{ M})$$

$$\epsilon = \frac{0.50}{1.1 \times 10^{-4} \text{ cm} \cdot \text{M}}$$

$$\epsilon = 4.5 \times 10^3 \text{ cm}^{-1} \text{ M}^{-1}$$

- c. (6 points) Below is a titration curve between a weak acid and a strong base.



yellow:  $\leq 3.8$   
blue:  $\geq 5.4$

If bromocresol green were used as an indicator in the titration, what color would the solution be after the following amounts of base were added during the titration?

- After 2.50 mL of NaOH was added in the titration: yellow
  - After 16.00 mL of NaOH was added in the titration: yellow-green / green
  - After 22.50 mL of NaOH was added in the titration: blue
- d. (4 points) Would bromocresol green be an appropriate indicator to use for the titration in Part (c)? Provide a brief explanation to support your answer.

Is bromocresol green an appropriate indicator for the titration (circle one):

YES

**NO**

Brief Explanation:

3.8-5.4 Its color change occurs ~~after~~ before the equivalence pt ( $\sim \text{pH} = 8$ )  
The endpoint of such a titration would not be the same as the <sup>true</sup> equivalence point, instead giving a volume of titrant that is too low and a concentration of the weak acid that is too low. The endpoint is just too soon. 6



Q3. A student in the lab pipets 20.00 mL of  $\text{H}_2\text{SO}_4$  with unknown concentration into a beaker and adds approximately 30-mL of distilled water. The student then titrates the solution with  $0.210 \pm 0.002 \text{ M NaOH}$  solution and tracks the pH of the solution during the titration with a pH meter. The solution was fully neutralized once 15.24 mL of the NaOH solution were added.

- a. (4 points) Calculate **both** the molarity and normality of the original  $\text{H}_2\text{SO}_4$  solution. You may assume both protons dissociate completely

$$\begin{aligned}
 & \cancel{(0.02000 \text{ L } \text{H}_2\text{SO}_4)} M_A = \cancel{(0.01524 \text{ L NaOH})} (0.210 \text{ M NaOH}) \\
 & V_B N_B = V_A N_A \\
 & \cancel{(0.210 \text{ mol NaOH})} \left( \frac{1 \text{ equiv OH}^-}{1 \text{ mol NaOH}} \right) \left( \frac{15.24 \text{ mL}}{1000 \text{ mL/L}} \right) = (20.00 \text{ mL}) N_A \\
 & N_A = 0.160 \frac{\text{eq H}^+}{\text{L}} \cdot \frac{1 \text{ mol } \text{H}_2\text{SO}_4}{2 \text{ eq H}^+} = \boxed{0.0800 \text{ M}}
 \end{aligned}$$

Molarity of  $\text{H}_2\text{SO}_4$ : 0.0800 M Normality of  $\text{H}_2\text{SO}_4$ : 0.160 N

- b. (4 points) Calculate the % inherent error associated with the concentration of the original  $\text{H}_2\text{SO}_4$  solution. The 20.00 mL of the original  $\text{H}_2\text{SO}_4$  solution was transferred by using a 10-mL volumetric pipet twice. The precision of various glassware can be found on Page 2 of this exam.

$$\begin{aligned}
 \frac{\Delta C}{C} &= \frac{\pm 0.02 \text{ M}}{0.210 \text{ M}} + \frac{2 \times \pm 0.04 \text{ mL}}{2 \times 10.00 \text{ mL}} + \frac{\pm 0.03 \text{ mL}}{15.24 \text{ mL}} \\
 &= 0.1 = \boxed{10\%} \text{ error}
 \end{aligned}$$

20.00 mL  $\rightarrow$  10 pip NaOH conc buret

- c. (2 points) The student repeated the titration two more times and calculated %RAD for the concentration of  $\text{H}_2\text{SO}_4$  to be 1.6%. Considering your answer in Part (b), what can you conclude about the experimental results?

Because % RAD is less than the inherent error, the measurements are precise.

$$1.6\% < 10\%$$

- d. (2 points) Briefly explain why the student added water to the beaker containing the original  $\text{H}_2\text{SO}_4$  solution.

It increase the volume of the solution in the beaker so that the electrode of the pH meter is covered. The addition of water doesn't affect the equivalence point because the number of moles of acidic protons to be titrated has not changed. Covering the electrode w/ solution ensures the device works properly.